REMARKS

Careful consideration has been given by the applicants to the Examiner's comments and rejection of the claims, as set forth in the outstanding Office Action, and favorable reconsideration and allowance of the application, as amended, is earnestly solicited.

Applicants note the Examiner's objections to the Abstract of the Disclosure and, accordingly, in order to fully meet the Examiner's requirements, applicants herewith enclose a new replacement Abstract of the Disclosure, which provides for terminology, as requested by the Examiner. However, applicants respectfully draw the Examiner's attention to the aspect that the minimum length of 50 words, as set forth in the MPEP is an optional requirement, and generally, shorter Abstracts are permitted. However, the present newly presented Abstract of the Disclosure meets the Examiner's requirements in that regard, by being lengthier than 50 words, but shorter than 150 words.

Applicants further note the Examiner's objections of the Claims 1, 4, 6, 9, 11 and 14, due to minor informalities, and appropriate amendatory action has been taken in that regard to render moot the formal grounds of objection.

Applicants further note the Examiner's rejection of Claims 1-15 under 35 U.S. C. §102(e) as being anticipated by Granik, et al., U.S. Patent No. 6,928,634, wherein the Examiner specifically, in Paragraphs 7-10 of the Office Action, details the particular grounds applied to the rejection of the claims.

However, applicants respectfully traverse the Examiner's rejection of the claims as being anticipated by Granik, et al., or even considered as unpatentable or obvious thereover, inasmuch as the claims, as presently on file and as formally amended, clearly and unambiguously distinguish over Granik, et al.

Concerning the forgoing, and directed to the language of the currently pending claims on file in comparison with the disclosure of Granik, et al., applicants respectfully submit the following arguments in traverse of Granik, et al.:

The present invention is concerned with adjusting lithographic mask shapes to improve lithographic performance. The prior art in this area, including Granik et al., is concerned, directly or indirectly a distinction, as explained below, with constraints on the printed image shapes that take the form of equations [1] and [2] on page 4 of the application application, i.e. they impose fixed requirements on the printed position of each edge. However, the present invention optimizes the printed images under constraints of the more flexible form given by equation [3], on page 4 of the application. Constraints 1 and 2 apply to individual edges, requiring of a given edge that it either be printed at a specified fixed position [eq. 1], or that it be printed within a fixed band of allowed positions [eq. 2]. In contrast, [eq. 3] is a linked requirement between a pair of edges. Constraints of this form do not mandate a specific position for any individual edge.

This lack of a specific required position or allowed range of positions for printed edges renders the maximization of lithographic process window more challenging. In contrast, when optimizing under the prior art constraint forms [eqs. 1 and 2], one can determine the dose acceptability, or dose margin, that a particular trial mask solution achieves simply by evaluating the image intensities at particular fixed points; for example at the points p_sub_j for constraints of the [eq. 1] type, or at the points p_sub_j + d_sub_j and p_sub_j - d_sub_j for constraints of the [eq. 2a] type. After making a pre-calculation of the image formation parameters that apply at these specific points, the prior-art optimization of the mask shapes can then proceed relatively rapidly. However, with constraints of the [eq. 3] form, the range of acceptable positions for the (j+)th edge will depend

on the printed position of another edge, namely x_sub_j-, which in turn will vary with dose and with the current choice of mask shapes. This makes it impossible to determine a set of pre-calculated factors to apply at a fixed set of positions.

However, the present invention is able to reduce the complex problem of adjusting mask shapes under [eq. 3] constraints to almost the simplicity attained by adjusting under the prior-art [eqs. 1 and 2] constraints. A key step in doing so is to add constraints that temporarily limit the motion of the edges to a restricted range, which applicants refer to as a "trust region". This is explained in paragraph (38) of the application, on page 10. The application then shows how adjustment of the mask shapes to maximize process window can be accomplished with roughly the same volume of computation as with the prior art, so far as the optimization loop corresponding to a particular trust region is concerned. If some printed positions have moved to the edge of the trust region when a loop of optimization is complete, [eq. 14] shows how the trust region needs to be shifted and the optimization repeated. That repetition does slow the overall procedure down compared to simple optimization under [eqs. 1 and 2] constraints, but the slow-down is only by a moderate factor, making optimization under the more flexible [eq. 3] constraints feasible in many cases, as explained in paragraph 35 (page 9) of the application.

Thus, two key aspects of the present invention are (1) the use of flexible constraints in the [eq. 3] linked form (which applicants call "linked constraints"); and (2) the use of trust regions to make rapid optimization under these linked constraints possible.

Applicants note that the present invention adjusts mask shapes to optimize lithographic process window while at the same time ensuring that constraints, including linked constraints, are satisfied by the optimized solution.

The invention in the disclosure of Granik, et al. is used under a different optimization framework. Specifically, instead of finding a feasible solution that provides the best possible process window, as the present invention does (where feasible means satisfy a set of constraints), Granik et al. formulate the lithographic optimization problem as minimizing what in our terms would be the errors by which the various edges fail to meet tolerances that are applied to them, i.e. Granik et al. minimize image errors or deficits where applicants' formulation would impose constraints. For example, Granik et al. put emphasis on optimization of edge position, in which case the error to be minimized at a particular edge is made the distance of the printed edge from a target position, a quantity Granik et al. refer to as edge placement error (EPE). When Granik et al. optimize the mask with EPE as an optimization goal, they are attempting to reduce the EPE at each edge, rather than optimizing the mask under a constraint that the EPE be zero at the given edge as would be done in the framework of the present invention (using [eq. 1] of the application to express such a constraint). More generally, rather than trying to find the best mask that is feasible under a set of constraints as applicants do, the invention of Granik, et al. essentially aims instead to make the mask feasible. When Granik et al. optimize masks to reduce EPE there is a degree of similarity to the present optimization under an [eq. 1] constraint, but the connection is an indirect one.

Another particularly important difference between Granik et al. and the present invention is that the various errors and deficits, such as EPE, that Granik et al. seek to minimize, all refer to requirements that in applicants' formulation would involve constraints of a form similar to those in [eqs. 1 and 2] of this application; more specifically, they involve requirements that are associated with individual edges, whereas the present invention is particularly concerned with linked constraints like [eq. 3]; whereby such linked constraints are at the crux of the present invention. Granik et al. do

generalize the goals that they optimize beyond those in [eqs. 1 and 2], but they do so in a way not relevant to the present invention; whereby specifically they consider other quantities to optimize besides the position error of each printed edge, such as the slope of the image at the printed edge. However, this generalization by Granik et al. still maintains a basic limitation of [eqs. 1 and 2], in that they associate each instance of a quantity to be optimized with particular edges. Thus, claim 1 of Granik et al. refers to "two or more objectives for each edge that can be optimized", while Claim 7 speaks of "each object having a number of edges with an objective that can be optimized".

For these two reasons (optimization outside a constraint framework, and use of optimization goals that are associated with individual edges rather than use of linked constraints), Granik's invention takes place in a framework that is incompatible with the presently claimed invention, so it is no surprise that its specifics are quite different from applicants' invention. In particular, the invention of Granik et al. is essentially a method for determining how neighboring features in masks should be adjusted in order to reduce the position error occurring at each printed edge in the neighborhood, or more generally how to adjust the neighboring features to a printed edge in order to improve some other quantity being optimized at the printed edge. This is done by constructing what are essentially sensitivity matrices, and comparing the numerical matrix entries to decide which specific adjustments to make.

<u>Unlike the present invention, Granik et al. are not concerned with constraints that link edges, and therefore they do not develop the concept of a trust region, as applicants' invention does</u>. (The present application shows how trust regions allow problems involving linked constraints to be reduced to the simplicity of problems with constraints that involve each edge separately, so long as the edges remain within the trust region). <u>It is therefore not surprising that the text in Granik et al.,</u>

which the Examiner cites as anticipating the linked constraints and trust regions of our claims, in fact refers to other things, and has nothing in common therewith.

In particular, applicants note that the Examiner cites as reading on applicants claim element "specifying a set of linked constraints on allowable positions for the edges of said circuit features" a great many lines of text from Granik et al.; however none of this Granik et al. text involves linked constraints. Specifically, the abstract of Granik et al. cited by the Examiner says nothing about any kind of constraint, much less linked constraints. Col. 1, line 38 to col. 2, line 7 of Granik et al. describes several things, but not linked constraints; it begins with criteria for optimization which are not the same as constraints and which are certainly not linked constraints; then their text describes the process of adjusting mask features to bring an edge to its proper position, which as discussed above differs from use of a constraint because it involves minimizing an error in satisfying what would otherwise be a constraint, and more importantly it differs significantly from our invention in minimizing an error that in the present framework would be the error in satisfying a constraint of the form of [eq. 1], rather than an error that could be associated with a linked constraint like appilcants' [eq. 3]. The Granik, et al. text then describes dividing printed patterns into edge fragments; then it describes running simulations to calculate the errors in positions of printed edges, which again differs from the present inventive treatment of edge position requirements, which for the case of EPE errors like those considered by Granik et al. would involve applicants using a constraint like [eq. 1], and which certainly bears no resemblance to a linked constraint like in [eq. 3]; the text then describes adjusting the mask to reduce the position error, which again differs from the present method of optimization under a constraint, and does not at all involve a linked constraint as the claimed invention does.

Applicants note that the Examiner further cites as reading on this claim element of ours ("specifying a set of linked constraints on allowable positions for the edges of said circuit features") Figs. 3A-3B of Granik et al., which show mask edges and sensitivity matrices, but show nothing involving linked constraints. The Examiner further cites a long block of text from col. 3 line 56 to col. 5 line 12 as reading on applicants' claim element; this text describes the circuit elements and associated edge fragments shown in Fig. 3A; information for each edge that may be stored in a database; an overview of lithographic exposure processing and mask adjustment; the optical interaction between a particular printed edge and the mask features within the neighborhood (optical radius) of the corresponding mask position; a sensitivity matrix that quantifies the strength of that interaction; the specific structure of such a sensitivity matrix in the cases of edge position error and edge slope; the generalization of the optimization criteria to include, for example, quantities associated with a cutline through the edge; the Fig. 3B example showing that the mask shapes can include shapes which do not print as edges on the wafer; the rectangular (non-square) sensitivity matrices that result when some mask shapes do not print and so give rise to a larger number of neighboring mask edges for each printed edge than there are printed edges; and finally the possibility that the segmentation initially chosen for breaking the edges into fragments could be changed during the course of optimization. None of this involves linked constraints (like our [eq. 3]), as are called for in the claim element in question; in fact linked constraints are not called for anywhere in Granik et al.

Similarly, there is nothing in Granik et al. about employing a trust region, a term applicants use for part of the idea of adding constraints that temporarily confine the excursion of edges to a certain bounded range (the trust region). To allegedly show that Granik et al. anticipates our claim

element for "initially centering trust regions at the preliminary locations of said circuit feature edges", the Examiner cites two portions of Granik et al. that have already been described in the previous paragraph, namely Fig. 3A and col. 3, line 56 to col. 4, line 54. As noted above, none of the topics discussed in those sections of Granik et al. involve trust regions, nor does Granik, et al. cover them elsewhere. The Examiner also cites as reading on this claim element of applicants, col. 5, lines 32 to 44 of Granik et al. This text describes the division of the edges in each target layer (or in the mask area conjugate to the edges in the target layer, since some mask edges may not print) that are within the same optical neighborhood of one another, i.e. that are close enough to a particular fragment to affect the printed position of that fragment (see also col. 4, lines 19-24). Such an interaction neighborhood (referred to by Granik et al. as a section) is quite different in meaning from the present trust region, which is a bounded range of allowed displacement that is temporarily imposed on a given edge, enforced by temporary constraints that are changed when the trust region is moved after each loop of optimization. Granik et al. nowhere disclose this idea of a trust region.

In view of the foregoing arguments and amendments, which are deemed to fully traverse the Examiner's grounds of rejection and which emphasize the inapplicability of Granik, et al. to the invention and particularly to the claims as currently pending, the early and favorable reconsideration of the application and allowance thereof by the Examiner is earnestly solicited.

However, in the event that the Examiner has any queries concerning the instantly submitted Amendment, applicants' attorney respectfully requests that he be accorded the courtesy of possibly a telephone conference to discuss any matters in need of attention.

Respectfully submitted,

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Attachments: New Abstract of the Disclosure